Opponents Report on PhD Thesis presented by Ms Yee Van FAN, MPhil

entitled:

"Minimising emissions footprints in circular economy by process integration"

Reviewer: Prof. Dr. Sandro Nižetić, Univeristy of Split, Split, Croatia

I studied and reviewed the presented Thesis with high interest as they bring a number of new interesting research achievement.

The Thesis consists of six chapters.

Chapter 1 is an introduction chapter focused on the general issues towards environmental footprints indicators for different source sectors. The most important impacts to the environment were discussed and analysed in detail, such as GHG emissions, water footprint, nitrogen footprint, land footprint, etc. The importance of process integration methodology was as also discusses as well as concept of circular economy as efficient tools for reduction of emissions and other harmful impacts. Chapter is finalized with clearly defined main aims of the thesis with respect to the discussed sustainability issues in general. Tools and methods were also discussed briefly as well as also considered case studies (transportation, pyrolysis of biomass), on which novel proposed approach would be demonstrated.

In Chapter 2 author provided deep and comprehensive overview of the existing research findings that were relevant to the aim of the thesis. Conducted review was focused on the circular economy concept with respect to the emissions and footprints to the environment, waste treatment and transportation issue. Emission footprints and environmental prices were also discussed, especially in transportation sector with detail analysis of GHG emissions. Decision making tools and low emission process design approaches were also elaborated in the considered chapter. Waste treatment management problem was discussed with especially focus on waste flows and waste management issue in EU, with detail elaborated topic focused on the transportation. Finally, problematic of process integration, Pinch Analysis and P-graph was also elaborated, importance and potential applications. Conducted review clearly addressed and critically elaborated main issues in the field and summarized the main research gaps as basis for the research contributions.

In the Chapter 3 the novel breakeven decision making tool was developed, formulated and presented in detail as an efficient tool for emission planning. Developed tool was applied for analysis of transportation modes as well as to the application of the biomass pyrolysis. The main novelties were focused on development of the new graphical tool where traveller distance and load were introduced to minimise harmful emissions. Furthermore, an analytical approach was also developed as basis for the proposed novel graphical tool. Finally, the total environmental burden was determined to analyse in deep different transportation modes. Novel developed model found to be an efficient tool to determine transportation options that are the most viable from environmental point of the view. Developed graphical tool is clear and useful since it can

consider different fuel types with respect to the impact of the grid mix. The main outcome of the analysis conducted for transportation section is highlighted importance of the further development of the lightweight vehicles, where SO_2 and NO_x found to be most critical regarding environmental sustainability in transport. The second case study was focused on pyrolysis of biomass where again effectiveness of the proposed novel approach was proved and which allows biomass utilization with highest profit and with lowest GHG emissions. The main advantage of the proposed approach is intuitive graphical display, which is more clear when compared to the convectional mathematical programming models. Proposed approach is novel, efficient and found to be effective and useful tool for considered case studies.

Chapter 4 deals with pinch analysis towards minimization of the emissions from the waste management system and biomass management. Comprehensive and detail modelling has been demonstrated, where emission intensity was modelled and finally applied on a case study for EU countries with respect to the waste management. Applicability of the novel developed model was proved and demonstrated. Furthermore, analysis was extended to the biomass management where optimisation model was developed and discussed to minimize overall costs. Pinch analysis was successfully implemented together with mathematical optimization to ensure energy demands with respect to the fluctuating biomass supply. Biomass allocation was also optimized to reduce costs due to transportation. Finally, pinch analysis, i.e. developed model was implemented for production, inventory and storage planning. Overall, complex problems were successfully solved in considered case studies and resulted with original research contributions.

Chapter 5 deals with application of the P-graph on the waste management system. The author demonstrated that P-graph was found to be suitable optimisation tool for waste management system. Optimisation procedure was developed with consideration of different treatment solutions. Identification of optimal, as well as, near optimal solutions was obtained. Finally, optimal waste management structure was demonstrated and applied on specific case study. Case study was focused on anaerobic digestion, where main novelty was detail analysis of environmental footprints as combination of P-graph and environmental assessment tool. Gained research contributions are useful for proper selection of pre-treatment and post-treatment methods.

Chapter 6 summarizes the main research findings, discusses overall research work and provides guidance for the future research work.

The dissertation contains interesting and original results and demonstrates up-to-date knowledge of the Candidate in a wide range of areas mainly linked to the sustainability issue, process integration and circular economy concept. The presented work has got strong theoretical contributions as well as practical contributions. Several case studies were analysed from the real-life with strong practical relevance and useful practical knowledge. Gained, original research contributions in these work provides the further development of the circular economy concept, process integration approaches, and finally it ensures better understanding of the cause-side effects that have strong impact on sustainability in general.

The Candidate has demonstrated respectable theoretical knowledge and capability to examine and to apply developed approaches to the real-life problems.

Questions for candidate:

1) Please highlight and briefly discuss your main research contributions?
2) Address practical relevance of your research findings and discuss potential suitability for industry purposes?
3) Page 85, Figure 4.5. Please discuss more in detail optimisation output for Container Ship and Electric Train, i.e. decision making procedure. What is specific when compare these transport options?

Regarding publications, the Scopus database references 30 papers of the Candidate, and reports 231 citations to them. All these appeared in highly reputable academic journals, which just demonstrates candidate excellence.

This high-quality research and development activities completely justify the awarding of the PhD degree to Yee Van Fan

I fully support awarding PhD degree.

Split, 28 October 2019

Prof. Dr.sc. Sandro Nižetić
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